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Low Carbon Scenario for An Energy Import-Dependent Asian Country: The Case Study of Sri Lanka

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Abstract

The energy sector of a country is the backbone in which a country's industrial competitiveness is built. It is imperative that a well-functioning energy sector is present to facilitate the growth of a country. That being said, the environmental wellbeing of the country and the entire world is important. The energetic analyses of the power, transport and industrial sectors of Sri Lanka are presented in this paper, along with possible Low Carbon scenarios (LCS). The Low Carbon scenarios are assessed for the CO_2 mitigation, energy consumption reduction and also for co-benefits such as energy security and productivity. The Sri Lankan energy sector is modeled using Asia-Pacific Integrated Model AIM/Enduse. Results show that Low Carbon activities in Sri Lanka increase energy security of the country. Mitigations of 41.3%, 25% and 37% are achieved in the most ambitious LCS, when compared to the business as usual (BAU) case in 2050, in the power, industry and transport sectors, respectively. Along with this, in all LCS, the diversity of the fuel share increases, while increasing the renewable fuel share. This also reduced the oil dependency of these sectors, thus reducing the cost burden of the Sri Lankan economy.

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Keywords: Low Carbon Society; Energy security; Sri Lanka; CO_2 mitigation; AIM/Enduse

1. Introduction

The energy sector of a country is vital to the achievement of development-based objectives of a country. The developing countries are at a crossroad as to conflicting objectives. On the one hand they have to aim to be more competitive in terms of economic growth and wellbeing, but on the other hand,

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they are faced with challenges in procuring energy sources, which aid in propelling them towards economic security. In addition to this, the world, as a whole is waking up to the realization that energy sector and its use and economic growth should be attained sustainably.

Sri Lanka is a South Asian island country, situated in the middle of the Indian Ocean. In 2010, its total energy demand was approximately 8.8 Mtoe, which lead to 13.12 Mt-CO_2 of CO_2 emissions [1]. Sri Lanka is still very much reliant on the agricultural sector of the economy. Yet, Sri Lanka has seen a burgeoning growth in energy demand in the last two decades. From being a hydropower-reliant power sector, Sri Lanka has become reliant on fossil fuel power plants which place a burden on the economy [2]. Sri Lanka is also susceptible to high oil prices as it does not possess any significant reserves of conventional fossil fuels or coal. In addition to this the domestic energy demand is still dominated by conventional biomass use in the rural areas. Ultimately, Sri Lanka is very much dependent on imported fossil fuels, thus making it vulnerable to developmental setbacks [2].

The objective of this paper is to identify the extent of CO_2 mitigation possible through Low Carbon scenarios in Sri Lanka in high-emitting energy sub-sectors and to quantify the co-benefits which accrue through the mitigation.

2. Methodology

The power, transport and industrial sectors of Sri Lanka, which account for approximately 80% of its total CO_2 emissions from the energy sector, are modeled using AIM/Enduse. The AIM/Enduse is a recursive dynamic optimization model, based on technology based bottom-up principle [3]. Each sector is modeled separately and with the extent of detail, whereby it is close enough to represent the actual system but, not overtly more complicated than necessary. The time horizon for the model is 2010 to 2050.

The power sector is primarily divided into carbon based and non-carbon based generation plants. Non-Carbon based power plants include significantly large hydro power plants. The industrial sector is divided into nine sub-sectors, with the energy demand of each sub-sector being accounted for separately. The transport sector is divided into freight and passenger travel demand.

The past data have been gathered from governmental publications such as [1] and [4]. The future plans have been gleaned from various governmental sources. For the power sector, the governmental generation expansion plan has been used [5] and for the future of transport sector, ministerial sources [6] have been used. The future energy consumption in each sector has been estimated individually by linear multi-variable regression models, where the independent variables are the value added in each sector, and the population of Sri Lanka.

This study presents a BAU case, which has frozen efficiency characteristics and maintains the status quo, along with three Low Carbon Society (LCS) scenarios with varying degrees of LCS measure implementation. These LCS scenarios are named LCS1, LCS2 and LCS3. LCS1 has lower levels of LCS measures implemented in it, whereas LCS2 has moderately higher levels of LCS measures and LCS3 has very high aspirations of LCS measures. The counter-measures (CMs) in the LCS scenarios are many fold. In the case of the power sector they include efficiency improvement in existing power plants, and advanced technologies in the new ones, along with renewable energy generation, both and non-grid. In the case of the industrial sector CMs include higher efficiency biomass based heating technologies and higher efficiency in electrical devices such as motors, and cooling. In the transport sector CMs include higher fuel efficiency in road vehicles, including lesser vehicular emissions, sustainable transport modes including bus rapid transit and the infrastructure installation to carry out bio-fuel based transport fuels. Most of these measures have been obtained from international reports [7] and some plans in existence in the case of Sri Lanka.

3. Results

Each sector results are presented in this section. The CO_2 emissions in terms of each sector, along with the behaviour of energy security are presented for each sector. Energy security is measured along the lines of diversity of primary energy demand (DOPED), oil share (OS), and renewable fuel share (RFS).

3.1. Power Sector

The Figure 1 presents the CO_2 emissions in the power sector of Sri Lanka. It can be seen that the emissions are very much reduced in the LCS3 scenario. Even though the mitigation is less in LCS1 scenario, both LCS2 and LCS3 scenarios show positive signs in mitigation. LCS3 scenario leads to a reduction of 41.3% in CO_2 emissions in 2050, when compared to the BAU case. Cumulatively, this represents 166.8 Mt-CO_2.

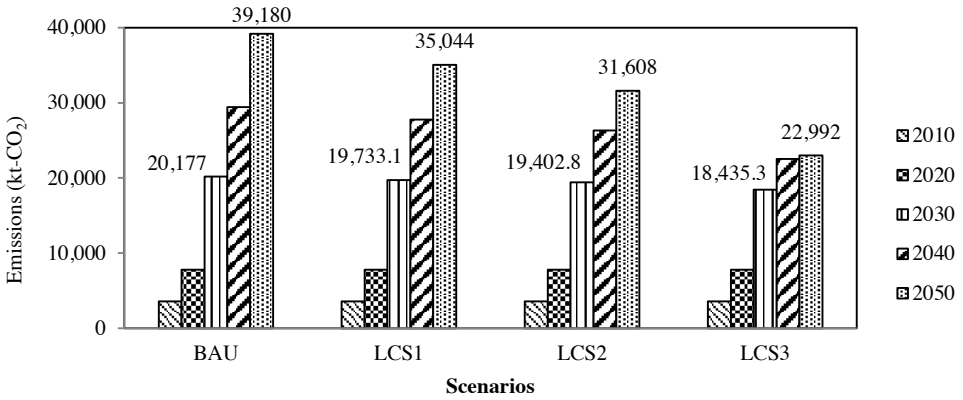

Fig. 1. CO_2 emissions of the power sector of scenario for selected years

Table 1 gives the energy security indices of the power sector of Sri Lanka. Diversity of the fuel share (DOPED) increases when compared to the BAU case in all the LCS scenarios, especially in the LCS3 scenario, which has higher participation from a diverse range of renewables such as small and pico hydro power plants. The same holds true for oil share (OS). The oil share decrease drastically in the LCS2 and LCS3 scenarios, signifying a savings in terms of cost of oil import for a cash-strapped country such as Sri Lanka. There is a palpable increase in the renewable fuel share (RFS) as well, which will also indirectly lead to higher job opportunities and better quality of life, with endemic energy resource use.

3.2. Industrial sector

The Figure 2 presents the CO_2 emissions in the industrial sector of Sri Lanka. The emissions don't reduce drastically in the LCS1 and LCS2 scenarios, as it is to be expected, but there is significant reduction in the LCS3. The reasons for the reduced reduction are that along with the LCS aspirations being low in LCS1 and LCS2 scenarios, the industrial sector is also heavily dependent on conventional biomass, which is accounted as being carbon neutral. There is a reduction of 25.2% CO_2 emissions in the LCS3 scenario, in 2050 when compared the BAU case.

Table 1. Energy security indices for the power sector of Sri Lanka

Years	Diversification of Primary Energy Demand (DOPED)			
	BAU	LCS1	LCS2	LCS3
2010	54.6%	54.6%	54.6%	54.6%
2030	58.9%	60.1%	62.9%	62.7%
2050	58.5%	59.6%	59.1%	63.9%
Years	Oil Share (OS)			
	BAU	LCS1	LCS2	LCS3
2010	69.2%	69.2%	69.2%	69.2%
2030	78.7%	78.2%	75.8%	76.2%
2050	74.3%	73.7%	70.6%	66.8%
Years	Renewable Fuel Share (RFS)			
	BAU	LCS1	LCS2	LCS3
2010	4.1%	4.1%	4.1%	4.1%
2030	2.8%	3.3%	3.4%	3.4%
2050	1.4%	4.4%	5.8%	10.2%

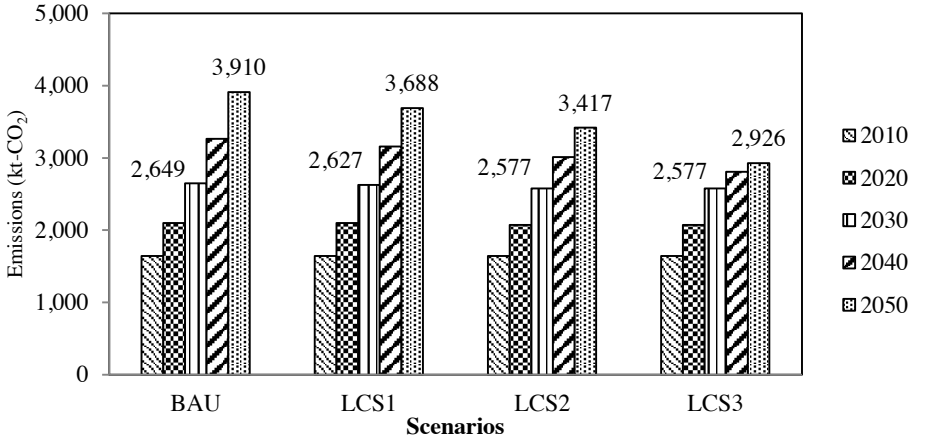

Fig. 2. CO_2 emissions in the industrial sector

Table 2 gives the energy security indices for the industrial sector of Sri Lanka. Even though the improvement in DOPED, OS and RFS seem small, in comparison to the improvement in the power sector, it should be said that the LCS scenarios don't negatively impact on these indices. Also, there is higher improvement in the indices in the LCS3 scenario, in comparison to the LCS1 and 2 scenarios, thus implying higher implementation of LCS measures is beneficial to the Sri Lankan energy sector. In the case of the BAU and the LCS3 scenario, the DOPED increases from 46.8% to 47.7%, where higher DOPED implies higher diversity and thus more energy security. Similarly, the RFS increases from 73.7%

in the BAU in 2050 to 74.9% in the LCS3 scenario. In the case of OS, lower values imply lower dependency on oil and thus more energy security, in case of Sri Lanka which imports 100% of all its oil requirements.

Table 2. Energy security indices for the industrial sector of Sri Lanka

Years	Diversification of Primary Energy Demand (DOPED)			
	BAU	LCS1	LCS2	LCS3
2010	46.4%	46.4%	46.4%	46.4%
2030	46.8%	47.0%	47.3%	47.4%
2050	46.8%	47.1%	47.2%	47.7%
Years	Oil Share (OS)			
	BAU	LCS1	LCS2	LCS3
2010	14.0%	14.0%	14.0%	14.0%
2030	14.2%	14.1%	14.2%	14.3%
2050	14.2%	13.1%	13.1%	12.8%
Years	Renewable Fuel Share (RFS)			
	BAU	LCS1	LCS2	LCS3
2010	74.0%	74.0%	74.0%	74.0%
2030	73.7%	73.7%	73.5%	73.4%
2050	73.7%	74.7%	74.7%	74.9%

3.3. Transport sector

As can be seen from Figure 3, the transport sector emissions show a very interesting trend in the future, in the LCS scenarios. The LCS2 and LCS3 scenarios exhibit a peak nature in terms of CO_2 emissions, which is not similar to the power and industrial sectors. The LCS scenarios also show a marked improvement in energy security, when compared to the BAU case. The total emissions reduction in 2050 in the LCS3 scenario is 37% when compared to the BAU case.

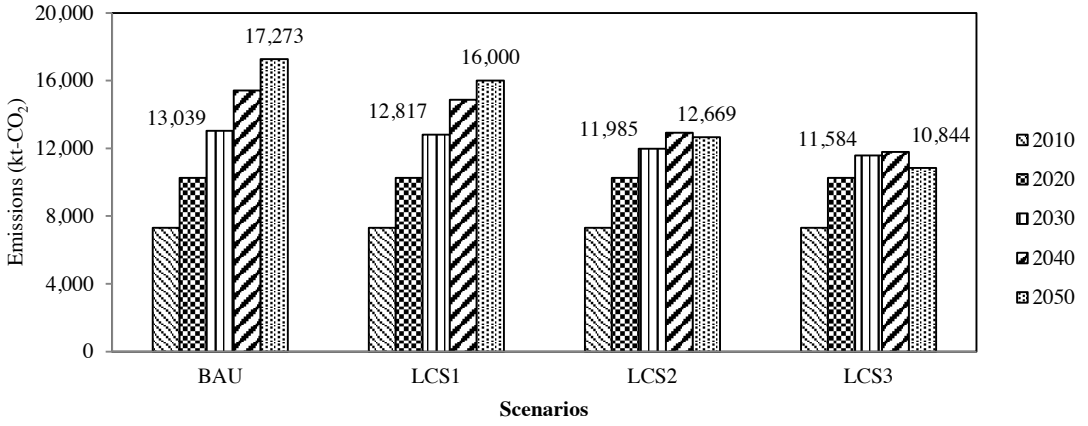

Fig. 3. CO_2 emissions of the transport sector of Sri Lanka

Table 3 gives the energy security indices of the Sri Lanka transport sector and it can be that there is a remarkable increase in most measures. In addition to drastically increasing the diversity of the fuel share in the LCS3 scenario, there is a drastic reduction in the oil share. The transport sector is an oil intensive sector in Sri Lanka since 100% of the fuel use is from oil. The reduction seen in OS, in the LCS scenarios is a significant benefit which needs to be seriously considered in the energy future of Sri Lanka. Most of

the OS reduction is obtained by the introduction of suitable and convenient public transit, along with the introduction of bio-fuels. Travel demand management and hybrids also help in reducing the OS.

Table 3. Energy security indices for the transport sector of Sri Lanka

Years	Diversification of Primary Energy Demand (DOPED)			
	BAU	**LCS1**	**LCS2**	**LCS3**
2010	25.8%	25.8%	25.8%	25.8%
2030	27.7%	31.8%	34.7%	37.7%
2050	27.7%	43.4%	49.9%	73.6%
Years	**Oil Share (OS)**			
	BAU	**LCS1**	**LCS2**	**LCS3**
2010	100.0%	100.0%	100.0%	100.0%
2030	100.0%	98.2%	95.8%	93.7%
2050	100.0%	92.7%	83.0%	60.2%
Years	**Renewable Fuel Share (RFS)**			
	BAU	**LCS1**	**LCS2**	**LCS3**
2010	0.0%	0.0%	0.0%	0.0%
2030	0.0%	0.5%	1.2%	2.0%
2050	0.0%	2.5%	7.3%	13.2%

4. Conclusion

The energy sectors of Sri Lanka are expected to show rapid growth in the coming decades, leading to higher CO_2 emissions, which are detrimental to the general environment. The low carbon activities which may be designed and implemented have a beneficial impact in reducing the CO_2 emissions. As such, the power sector, industrial sector and transport sector all show reduced CO_2 emissions, along with increased energy security. Mitigations of 41.3%, 25% and 37% are achieved in the most ambitious LCS scenario (LCS3), when compared to the BAU case in 2050, in the power, industry and transport sectors, respectively. The LCS3 scenario, which has higher shares of CMs introduced has higher energy security, with enhanced DOPED, OS and RFS. The LCS3 scenario also needs higher financing in terms of infrastructure costs.

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